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KIRK-OTHMER

**ENCYCLOPEDIA OF
CHEMICAL
TECHNOLOGY**

FOURTH EDITION

VOLUME **23**

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T

TACK. See RUBBER COMPOUNDING.

TACONITE. See IRON.

TALC

Talc [14807-96-6], a naturally occurring mineral of the general chemical composition $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$, is a crystalline hydrous magnesium silicate belonging to the general mineral family of the layered silicates. Other layered silicates are kaolin, mica, and pyrophyllite (1).

Geology and Occurrence

Talc deposits are of four types and each has a different group of accessory minerals (2). The most common type is of ultramafic origin, where talc is formed by alteration of serpentinite [12108-92-2], $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$, to talc-carbonate rock. This type of talc deposit is common in Vermont, Quebec, and Finland, and has magnesite [13717-00-5], MgCO_3 , and chlorite [14998-27-7], $\text{Mg}_3\text{Al}_3\text{Si}_4\text{O}_{10}(\text{OH})_8$, as accessory minerals. Talc content is typically in the range of 50 to 70%. Talc of mafic origin is common in Virginia, North Carolina, and Georgia. It is formed by the hydration of mafic rock to serpentinite, followed by alteration of the serpentinite to talc-carbonate. It is usually so badly contaminated by chlorite, quartz (SiO_2), and other deleterious minerals that it is rarely usable.

Talc of metasedimentary origin is formed by hydrothermal alteration of a dolomitic host rock by a silica-containing fluid. This type of deposit is typical of Montana and Australia. It is usually quite pure with talc content of 90 to 98% and often very white as well. Dolomite [17069-72-6], $\text{CaMg}(\text{CO}_3)_2$, is the

most common accessory mineral. The fourth type is of metamorphic origin, where a siliceous dolostone is first converted to tremolite [14567-73-8] or actinolite [13768-00-8] and then partially converted to talc. The Balmat, New York, and Death Valley, California, deposits are of this type. Tremolite, dolomite, and serpentine are common accessory minerals. This type of talc deposit has a variable talc content (30–80%), but is usually white and often commercially exploited because of the properties of its accessory minerals rather than the talc.

Mining and Processing

The commercial value of a talc ore is based on its color, purity, accessibility, proximity to the market, and accessory minerals. Of these the most critical is color. Most talc is mined by open-pit methods, but there are also underground mines in the United States, Canada, Italy, India, and China. In open-pit mining, overburden is removed and the talc is mined via conventional benching techniques. All the mining is highly selective, using much smaller shovels and trucks than those for conventional base-metal mining. Because talc ore is very sensitive to contamination during mining, it is always better to remove better-quality ore selectively during mining (high grade) than to leave this in the greater portion of the ore and try to beneficiate later. In many cases mechanical or hand sorting is done at the mine or in a separate process building close to the mine. A typical mine can produce multiple grades based on color, purity, and accessory minerals (Fig. 1). The ore is generally stored or shipped in lump (–15 cm (–6 in.)) form.

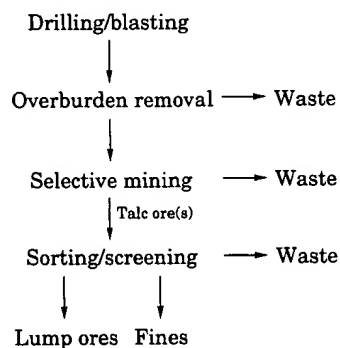


Fig. 1. Mining of talc.

There is some beneficiation of talc by froth flotation (qv), practiced especially on ultramafic-type deposits. In this process (Fig. 2), talc is milled to its liberation size (–100 mesh (ca 0.15 mm)) using ball mills or ring-type roller mills and then slurried at 10–30% in water. Flotation is done in conventional multistage float cells using methyl amyl alcohol as a frother. Typically two to four stages are required to upgrade the ore from 50–70% talc to 90–98%. The product is filtered and then flash-dried and milled to a final product.

Dry ore processing of talc is summarized in Figure 3. Lump ore is usually crushed to –2 cm (–3/4 in.) and then reduced in ring-roller mills to –200- or

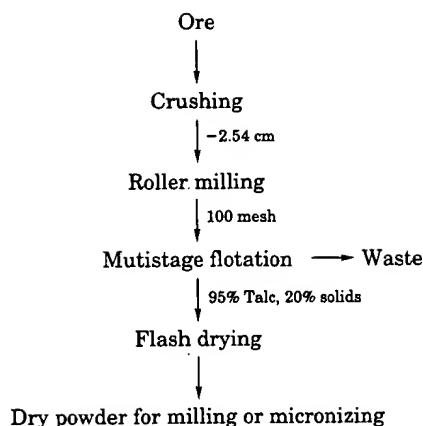


Fig. 2. Flotation of talc (100 mesh ≈ 0.15 mm).

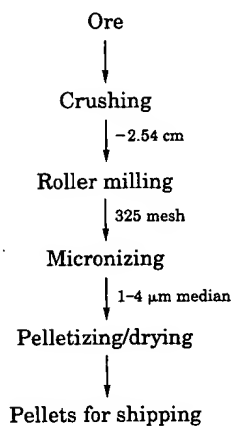


Fig. 3. Dry processing of talc (325 mesh ≈ 44 μ m).

-325-mesh (ca -74-44 μ m) products. This type of milling is preferred because it delaminates the talc and preserves its platy structure. Much product is sold in this size range. For finer products, the talc is further processed in micronizing mills to generate products with median particle sizes from 1 to 5 μ m and top sizes down to 10 μ m. Mills used included jet mills with integral air classifiers, fluid energy mills with external air classifiers, and hammer mills with integral air classifiers. Products are packaged and shipped in 50-lb (23-kg) bags or bulk sacks, but are also shipped as bulk powder. Because of its low bulk density when micronized, some talc is compacted and shipped in pelletized form. This is generally done by wetting the talc with water and processing through pellet mills. For paper applications, especially to control pitch deposits, the pellets are shipped with 2-10% moisture; for other applications such as rubber and plastics, however, the pellets are dried to <1% moisture.

Economic Aspects

According to statistics collected by the U.S. Geological Survey (3), U.S. production of crude talc in 1995 was 1,050,000 metric tons. Montana, Texas, Vermont, and New York were the principal producing U.S. states. Worldwide production was estimated to be 5,845,000 t. China, having 2,400,000 t, was the largest producer in the world; after China and the United States, Finland, India, Brazil, France, Italy, and Canada are the next principal producers. World production of talc in 1994 is listed in Table 1.

The value of crude ore produced in the United States was estimated to average \$32.50/t in 1994. Product pricing was reported to vary from \$99/t for New York State 200-mesh paint grade to \$220/t for ultrafine Montana paint grade. Cosmetic grades were quoted at \$263/t.

Table 1. 1994 World Production of Talc

Country and region	Production, 10 ³ t/yr
<i>North America</i>	
United States	935
Canada	130
Mexico	15
<i>Total North America</i>	<i>1080</i>
<i>Europe</i>	
Austria	130
Finland	400
France	275
Germany	21
Italy	165
Norway	50
Spain	65
others	37
<i>Total Europe</i>	<i>1143</i>
<i>Asia</i>	
Australia	210
China	2400
India	360
Japan	61
South Korea	60
others	50
<i>Total Asia</i>	<i>3141</i>
<i>Others</i>	
Brazil	320
Africa	11
CIS	150
<i>Total world</i>	<i>5845</i>

Properties

The crystal structure of talc, illustrated in Figure 4, consists of repeating layers of a sandwich of brucite [1317-43-7], $\text{Mg}(\text{OH})_2$, between sheets of silica [7631-86-9], SiO_2 . The layers of silica are not strongly bonded to each other (except for van der Waals forces) and thus it is easy to fracture talc along this surface, which corresponds to delamination. This surface is covalent and hydrophobic. If talc is fractured across the brucite layer, the surfaces generated are ionic and hydrophilic in nature. Thus talc has a natural balance of hydrophilic and hydrophobic surfaces, giving it surfactant properties and consequently the name soapstone which is used in many parts of the world.

The mineral talc is extremely soft (Mohs' hardness = 1), has good slip, a density of 2.7 to 2.8 g/cm^3 , and a refractive index of 1.58. It is relatively inert and nonreactive with conventional acids and bases. It is soluble in hydrofluoric acid. Although it has a pH in water of 9.0 to 9.5, talc has Lewis acid sites on its surface and at elevated temperatures is a mild catalyst for oxidation, depolymerization, and cross-linking of polymers.

Pure talc is thermally stable up to 930°C, and loses its crystalline bound water (4.8%) between 930 and 970°C, leaving an enstatite (dehydrated magnesium silicate) residue. Most commercial talc products have thermal loss below 930°C on account of the presence of carbonates, which lose carbon dioxide at 600°C, and chlorite, which loses water at 800°C. Talc is an insulator for both heat and electricity.

Talc products are also characterized by their crystallinity or relative platiness. Microcrystalline talc products typical of Montana and Australia tend to have very fine ($\sim 10 \mu\text{m}$) natural grain sizes and thus are easily milled to very fine products of higher surface area ($10\text{--}20 \text{ m}^2/\text{g}$). Macrocrystalline talc ores typical of Vermont and California have much larger grain sizes ($50\text{--}200 \mu\text{m}$). They tend to have a higher aspect ratio, lower surface area ($<5 \text{ m}^2/\text{g}$), and are much more difficult to micronize. A micrograph illustrating the platiness of a macrocrystalline talc is shown in Figure 5.

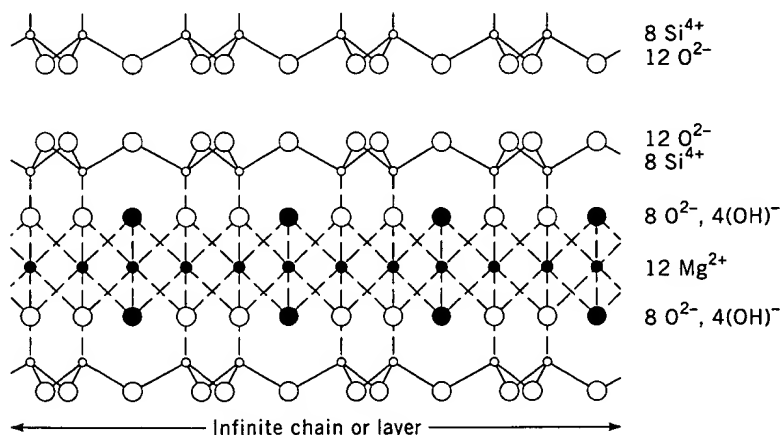


Fig. 4. Molecular structure of pure talc mineral.

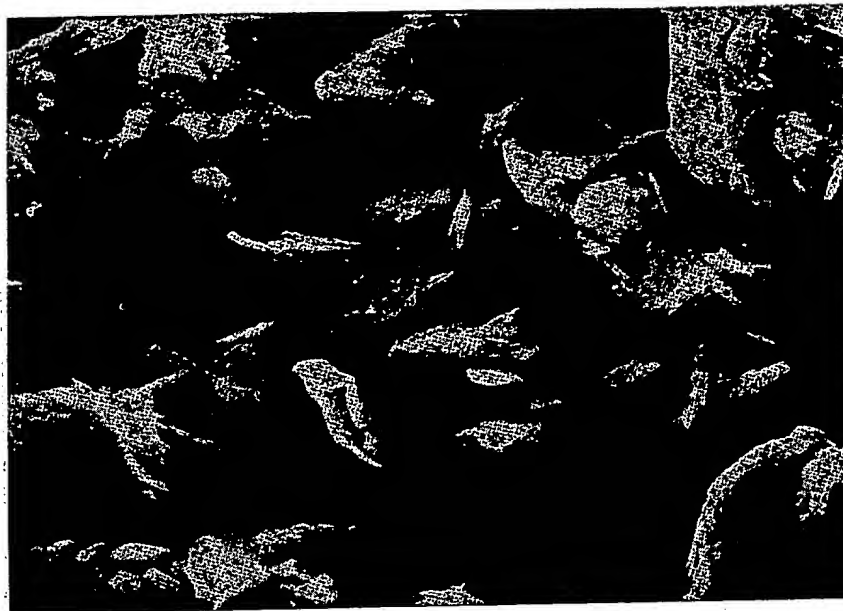


Fig. 5. Scanning electron microscope photograph of macrocrystalline talc at $\times 1000$.

Uses

Talc is sold for use in a wide variety of applications, including paper (qv), ceramics (qv), roofing, paint (qv), plastics, rubber (qv), cosmetics (qv), pharmaceuticals (qv), adhesives (qv), sealants (qv), and animal feedstuffs (see FEEDS AND FEED ADDITIVES). In all of these applications it is a functional ingredient with specific beneficial properties. Talc is rarely used as a filler because it is much more expensive than alternative minerals such as limestone and clay.

The market for talc in the United States based on the 1995 U.S. Geological Survey Annual Review (3) is summarized in Table 2. Ceramics was the biggest market, having almost 35% of the total, followed by paint, paper, and plastics. Outside of the United States, especially in Asia, paper is the principal application. In that region talc is available locally at lower cost than competitive minerals such as kaolin.

In many markets talc competes not only against alternative minerals, but also against chemicals and other materials. In the paper pitch control market, dispersants are the main competition. In plastic, talc-reinforced polypropylene competes against engineering polymers such as ABS and polycarbonate in automotive parts. In cosmetics, talc and starch are both used as the basis of baby and body powder formulations. Thus the processing and marketing of talc has a much greater similarity to the specialty chemicals industry than to the traditional mining industry sector.

Paper. Paper is the principal application for talc throughout the world. It is used as a filler, a coating pigment, and a process aid in pulping and deinking for pitch and stickies control. As a paper filler, talc is used because of its platiness, softness, whiteness, ability to space TiO_2 , and ink receptivity. It has

Table 2.

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Table 2. Uses for Ground Talc in 1995

Application	Volume, 10 ³ t/yr	% of Total
ceramics and refractories	265	34.7
paint	142	18.6
paper	121	15.8
plastics	45	5.9
roofing	38	5.0
cosmetics	31	4.1
rubber	19	2.5
other uses	103	13.5
<i>Total</i>	<i>764</i>	

better retention and bonding strength in the paper fiber than other minerals such as kaolin and CaCO_3 , but it is also more expensive. As a coating pigment, talc is used in rotogravure printing papers to improve printing quality and in offset coatings to give a matte (low gloss) finish. Talc is much more difficult to wet out in coating formulations than kaolin or CaCO_3 and special formulations combining kaolin, talc, and dispersants are required for optimum performance.

In conventional chemical pulping systems, micronized talc is used for pitch control. The mechanism is not well understood, but talc does adsorb on the pitch and detackify it, preventing it from agglomerating and attaching on equipment. In de-inking talc is used both to enhance ink removal in conventional screening/centrifugation methods and as a carrier in flotation systems.

Ceramics. In ceramics, talc is widely used in wall tile and hobbyware bodies, in electrical porcelains, and in cordierite formulations. Wall tile and hobbyware are talc-clay bodies that are pressed and fast-fired to a high porosity (bisque) and then glazed and refired to produce the final product. Talc containing tremolite and carbonate is preferred to ensure good porosity.

In electrical porcelains (often called steatite bodies), high purity talc products with low levels of alkali metals are preferred. A typical steatite is made from 85% talc, 10% plastic kaolin, and 5% BaCO_3 . Steatites are used as insulators on high voltage equipment such as automotive starters, microwave oven generators, and laser generators.

Cordierite [12182-53-5], $\text{Mg}_4\text{Al}_4\text{Si}_5\text{O}_{18}$, is a ceramic made from talc (25%), kaolin (65%), and Al_2O_3 (10%). It has the lowest thermal expansion coefficient of any commercial ceramic and thus tremendous thermal shock resistance. It has traditionally been used for kiln furniture and more recently for automotive exhaust catalyst substrates. In the latter, the cordierite raw materials are mixed as a wet paste, extruded into the honeycomb shape, then dried and fired. The finished part is coated with transition-metal catalysts in a separate process.

Roofing. Coarse talc products (-40 mesh) are widely used as both fillers and parting agents for asphalt-based roofing products. They are used as fillers in polymer-modified asphalt sheet products because they wet out easily and because they improve weathering and are inert to algal attack. Talc is used as a backcoating and parting agent on the backside of conventional fiber glass asphalt shingles. It coats the hot asphalt and prevents adjacent shingles from sticking to each other.

Paint. In coatings, talc is used for flatting, corrosion resistance, TiO_2 spacing, and as a general extender. Fine talc, because of its platy, disordered structure, can roughen the surface of a conventional solvent-cast coating on a microscale and reduce the gloss. The platy structure of talc reduces the permeability of all coatings to water and the inert character of talc makes it immune to weathering or acid attack. Platy talc is an excellent spacer of TiO_2 and can improve the opacifying efficiency of this expensive pigment.

Plastics. In plastics, talc is used as a reinforcing agent in polypropylene, an antiblock in polyethylene film, and a nucleating agent in nylon and injection-molded polypropylene (4,5). In polypropylene, -325-mesh (ca 44 μm) talc is used at loading levels of 15–40% to increase the stiffness, increase the heat stability, and reduce the shrinkage of homopolymer and copolymer injection-molding grades. In linear low density polyethylene film, a -500-mesh (ca 28 μm) talc is used at 0.5–1.5% to roughen the surface and reduce the tack of film so that it does not adhere to itself. Micronized talc (1–2 μm median particle size) is capable of promoting crystal growth in semicrystalline polymers such as nylon and polypropylene. At levels of 0.2–2% it is used to reduce cycle times in the injection molding and thermoforming of large parts.

Rubber. In rubber, talc is used as a reinforcing agent and processing aid in mechanical rubber goods and as a parting agent in a variety of thermoset rubber processes. Talc, micronized by fluid energy milling, is capable of increasing the modulus of typical cured synthetic elastomers by 300% at loadings of 100 phr and is used in a wide range of belt, cable, and hose applications. It is also a rheology improver and process aid for extruded rubber goods at use levels of 10 to 50 phr. Coarser (-200-mesh (ca 74 μm)) talc is an excellent parting agent for all types of molding applications such as tires, elastomeric thread, and printing trays.

Cosmetics. Talc is widely used in baby and body powders, pressed powders, creams, and antiperspirants. Its softness, slip, inertness (fragrance retention), and relative safety make this one of the oldest and most widely recognized applications for talc. Talc is also used in chewing gum as a detackifier and in tableting as a lubricating process aid.

Miscellaneous. Talc is used in gypsumboard joint compounds as a high end filler to promote smoothness, sandability, and sag resistance. It is used in automotive primers and polyester body repair compounds to promote sandability. It is used in a wide variety of caulking compounds to improve rheology and sag resistance.

In many parts of the world, eg, China and northern Canada, block talc is used by the native artisans as a carving material and some of the sculptures produced are widely treasured. Block talc is also used for manufacture of fireplaces in Finland and Vermont. Machined talc pencils have been used for marking steel during processing since the 1890s.

Specifications, Standards, and Test Methods

Most talc sold to paper, ceramics, and other industrial customers is manufactured to specifications agreed to between the producer and consumer. In paper, properties such as color, abrasion, surface area, and tint are most important, whereas in ceramics, oxide chemistry, fired color, pressing characteristics, and

alkali metal content are more important. There are some military specifications for talc used in corrosive coatings (6) and for cosmetic talc products used for cleaning of personnel in chemical warfare zones (7).

Talc sold to the cosmetics and baby powder markets must meet the Cosmetic, Toiletries and Fragrance Association (CTFA) specifications (8). For more stringent applications there are *United States Pharmacopeia* (USP) and *Food Codex* specifications.

Talc producers most commonly use screens for particle size analysis of coarser products (+325 mesh (ca 44 μm)) and the Micromeritics (Georgia) seditigraph for particle size analysis of finer products. The Hegman fineness of grind gauge is used for control of topsize.

Color is measured by a variety of machines using Tappi brightness, General Electric brightness, and Hunter L,a,b scales. Surface area is measured by nitrogen or argon adsorption using the BET method and loose and tapped bulk density using CTFA procedures. Mineralogy is characterized using x-ray diffraction and differential thermal analysis.

Health and Safety

Talc is considered a nuisance dust and subject to regulation in the workplace by both the Occupational Health and Safety Administration and the Mine Safety and Health Administration. Eight-hour exposure limits for talc dust are two milligrams of talc per cubic meter.

There has been a significant amount of litigation since the 1970s concerning the regulatory status of tremolitic talc products produced from the New York State and Madoc, Ontario deposits. In 1993 the U.S. federal government agreed that there were two forms of tremolite: so-called blocky tremolite and asbestiform tremolite. The first form is not regulated and the second is regulated as asbestos.

A thorough review of the health aspects of talc was presented in an FDA-sponsored seminar in Bethesda, Maryland, in January 1994 (9). The executive summary states that the probability of human risk is likely nonexistent under customary conditions of use. Used for decades in a wide variety of cosmetic and other applications, talc has proven to be among the safest of all consumer products.

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TALL OIL

Tall oil [8002-26-4] is a by-product of kraft pulping of pine wood. *Tall* is the Swedish word for pine, *kraft* the German word for strength. Crude tall oil (CTO), formed by acidifying black liquor soap skimmings with sulfuric acid, is a dark oily liquid with 26-42% resin acids or rosin, 36-48% fatty acids, and 10-38% neutrals. CTO is an excellent source of oleic/linoleic fatty acids and resin acids or rosin (1,2). Extensive fractional distillation is required, not only to separate these desirable products but also to remove the neutrals. The bulk of these neutrals, largely esters of fatty acids, sterols, resin and wax alcohols, and hydrocarbons, boil at either lower or higher temperatures than the boiling range of the fatty and resin acids. The wax alcohols and related components with boiling points in the rosin range are notable exceptions, but they are minor constituents.

Considering their heat sensitivity, the separation of fatty acids and rosin with minimal degradation by fractional distillation under vacuum and/or in the presence of steam is surprisingly good (3). Tall oil rosin (TOR) contains about 2% fatty acid and small amounts of neutrals. Tall oil fatty acid (TOFA) contains as little as 1.2% rosin and 1.7% neutrals. In typical U.S. TOFA, 49% of the fatty acids is oleic, 45% linoleic, and 3% palmitic, stearic, and eicosatrienoic acid. TOR and TOFA are upgraded to resins and chemicals for the manufacture of inks (qv), adhesives (qv), coatings (qv), and lubricants (see LUBRICATION AND LUBRICANTS).

The 1995 annual global CTO production was about 1.7 million metric tons. About half of that output was in the United States and one quarter in Europe outside the CIS. U.S. CTO production climbed 4.2% per year from 0.45 million metric tons in 1963 to 0.68 in 1973. After that the average annual increase slowed to 1%. The five U.S. CTO processors are listed in Table 1.

CTO prices are closely tied to the cycles of the U.S. economy and the paper industry. They vary between \$120 and \$220 per metric ton. In 1995 they were close to \$200/t (4). With 50% of pine wood being converted to linerboard valued at \$400-\$600 per ton, pulp manufacturers do not focus on optimum black liquor